Nikola Tesla

1856-1943

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The following account was prepared by the Chairman of the IRE History Committee, at the request of the Executive Committee, as a tribute to one of the most brilliant experimenters in electrical and radio phenomena on the occasion of the 100th anniversary of his birth.
—*The Editor*

THIS YEAR 1956 marks the Centennial of the birth of Nikola Tesla, acclaimed by some as the world's greatest electrician of his day. He was one of those particularly gifted with a generous number of talents. These included an encyclopaedic grasp of many fields of learning, an easy familiarity with several languages, thoroughness in the treatment of technical matters, the ability to lecture with tutorial facility, the writing of poems in more than a single tongue and the vision to create concepts in the applied sciences so far beyond the times that many years elapsed before instrumentalities became available so that they could be put to use.

Tesla's mind strode boldly ahead of current thinking. It was unfettered by the restrictions that blocked the efforts of others, and would blithely leap over these restrictions starting afresh with new ideas aimed to achieve a visionary end result on the road to which he would matter-of-factly indicate how important hurdles were to be conquered, whether or not the means for doing so were available.

Our existing industrial era would cease to function without Tesla's first and greatest contributions. His entry as a young man into the electrical era came when the future of electric power was in chaos and engineers were speculating as to whether the use of direct current should continue or alternating current should be made the standard. Direct current could be transmitted only a very short distance, but was suitable for running motors; whereas alternating current could be transmitted afar, but efficient motors for using it were nonexistent. His brilliant invention of the rotating electric field, making possible the very simple commutatorless, nonsynchronous, polyphase induction motor which required alternating current but eliminated the troublesome and costly brushes and commutators necessary for direct current use, cut the Gordian knot and established a need for the universal availability of polyphase power. The Tesla system was adopted for the first power plant at Niagara Falls, completed in 1895, which ushered in the era of polyphase power transmission. Today our vast power network is receiving energy from this original plant together with energy from the recently completed first atomic-energy generating facility.

An early important application of electricity was for street lighting, and Tesla devoted himself to improving arc lighting which, with normal alternating current power, produced an objectionable hum. He accordingly became interested in high frequency electric currents and, for the rest of his life, devoted himself primarily to experimenting with them. Hertz in 1887 first demonstrated the existence of electromagnetic waves, using for the source of high frequency power the relatively feeble oscillatory spark discharges of condensers. Tesla's lofty aspirations required high frequency power on a vast scale and at very high voltages. In 1891 he produced a rotating alternator having 384 poles and an output frequency of 10,000 cycles per second, followed by other machines developing up to 25,000 cycles per second. Tesla believed that undamped current generation was very important, but he was a quarter of a century ahead of the times, as this method did not come into practical use until after 1910. His early models used the inductor principle with stationary coils, which was the arrangement used for the huge commercial machines subsequently built for radio communication.

Rotating machines could not provide the high frequencies and voltages Tesla wanted, so he utilized principles that, he stated in his famous lectures, were well-known to electricians, such as tuned circuits, induction coils, and oscillatory spark circuits, which he combined with an oscillation transformer to create the spectacular luminous flaming arc discharge effects that brought his name to wide fame. He explained and demonstrated this apparatus and high frequency phenomena in a series of brilliant lectures, the first in 1891 before the American Institute of Electrical Engineers in New York, the second in 1892 before the Institution of Electrical Engineers and the Royal Institution in London, the Société Internationale Française des Electriciens and the Société Française de Physique in Paris, and the third in 1893 before the Franklin Institute in Philadelphia and the National Electric Light Association in St. Louis. In these lectures Tesla's galloping mind traversed the gamut of scientific thinking including speculations on the electrical nature of the structure of matter. In addition he had an extensive exhibit at the Chicago World's Fair in 1893. It was only a matter of a couple of years when practically every technical school of note throughout the world had a Tesla Coil apparatus. The impact of these teachings on high frequency research by both scholars and students was enormous.

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Tesla's revelations and accomplishments encompassed a wide variety of subjects. Early in 1890 he described how metal and dielectrics could be heated in the fields of specially designed high frequency coils, forecasting the commercial high frequency furnace and the present day dielectric heating industry. Experimenting on himself, he demonstrated the effect of high frequency currents on the human body, a technique now called diathermy. Prior to 1893, starting where Sir William Crookes left off, he further developed vacuum and gas-filled tubes adopting special types of glass and coating them with phosphors. He bent these luminous tubes to fit a room or to form words. Long after, neon signs appeared, and still longer after, fluorescent lamps were introduced. Tesla once commented that the way to efficiently conduct high frequency currents was by using a cable made up of many insulated small wires, but he observed such material was not available. In later years this appeared under the name of Litzendraht. One of the novelties he predicted was the use of cheap, synchronous electric clocks on a world-wide basis, and he demonstrated such clocks at the World's Fair in 1893. He said that the future of aviation, then nonexistent except for balloons, depended on the development and use of aluminum. It must be remembered that aluminum then was scarce and expensive to make and only became a practical material with the advent of the cheap and plentiful electric power needed for the reduction of its ore. Thus the aviation industry of today owes a substantial heritage to this unconventional mastermind. Tesla's disclosures in his early lectures, and patents on the generation of high frequency currents, described devices which became important many years later. For example, rotary spark gaps and series spark gaps with small spacings became basic elements in the wireless telegraph systems of the 1909 to 1920 period.

Tesla's versatility in creating uses for high frequency currents caused him, in his February, 1892 lecture, to forecast the possibility of transmitting power through space without the use of conducting wires. In that same month Sir William Crookes published a prediction that electromagnetic waves in space would be used for telegraphically communicating through space without the use of wires. Tesla's concept was to disturb the electrostatic condition of the earth, setting up standing waves on its whole surface by exciting it with high frequency power and then taking off power anywhere that wave amplitude was present. While Crookes did not discuss or pursue methods, Tesla, commencing with his 1893 lecture, described elevated antennas connected to the earth with wires for both transmission and reception, and pointed out the importance of applying the principle of electrical resonance to these arrangements, even making their tuning variable.

In 1896 he conducted experiments resulting in the transmission of signals some 25 miles to a Hudson River boat. To make continuous waves in a receiving system audible, he suggested the use of vibrating contacts, which years later became the accepted practice until the introduction of the heterodyne beat note method. In 1898 he demonstrated and patented a radio controlled vessel, the forerunner of the present-day guided missile. For this purpose he stated that "any waves, impulses, or radiations which are received through the earth, water, or atmosphere could be used" and that "vessels or vehicles of any suitable kind may be used as life, despatch or pilot boats, or the like, or for carrying letters, packages, provisions, instruments, objects, or materials of any description, for establishing communication with inaccessible regions and exploring the conditions existing in the same, for killing or capturing whales or other animals of the sea, and for many other scientific, engineering, or commercial purposes; but the greatest value of my invention will result from its effect upon warfare and armaments, for by reason of its certain and unlimited destructiveness it will tend to bring about and maintain permanent peace among nations." At the turn of the century Tesla talked about radio broadcasting saying: "I have no doubt that it will prove very efficient in enlightening the masses, particularly in still uncivilized countries and less accessible regions, and that it will add materially to general safety, comfort and convenience, and maintenance of peaceful relations. It involves the employment of a number of plants, all of which are capable of transmitting individualized signals to the uttermost confines of the earth. Each of them will be preferably located near some important center of civilization and the news it receives through any channel will be flashed to all points of the globe. A cheap and simple device, which might be carried in one's pocket, may then be set up somewhere on sea or land, and it will record the world's news or such special messages as may be intended for it." In 1917 he forecast radar by indicating the possibility of shooting out a pulsed concentrated ray of very high power vibrating at the tremendous frequency of millions of times per second and then intercepting it after being reflected from a hidden object and displaying this reflected ray on a fluorescent screen. The means for accomplishing these several concepts were not developed until twenty years or more later.

Tesla's idealized dream of causing the whole terrestrial globe to oscillate electrically engaged a great deal of his attention. He made extensive experiments at Colorado Springs in 1899 where he produced artificial lightning crashes 135 feet long. Later he constructed a 200-foot high tower on Long Island surmounted by a 70-foot metal sphere which was to be excited by millions of high frequency volts for broadcasting telegraphy, speech, vision, and power, but it was never completed. Tesla's indefatigable strivings to implement his apparently unclear and visionary concept did not succeed. He neglected to leave behind any clear record of conclusions from the Colorado experiments and other subsequent work. Unfortunately he was severely handicapped in later years because of lack of funds, not only for experimenting, but also for personal living. A friend once wrote of Tesla that the goddesses of Fame and Fortune are capricious, one of them having smiled on him but not the other.

Tesla characteristically seemed indifferent toward the commercial application of his ideas, preferring to follow the lure of new challenges. Since his basic objective after about 1893 was directed towards producing a world-wide series of grandiose electrical effects, the many ideas and items of apparatus which he produced were left for others to pick up and embody for less ambitious but more practical purposes. For this reason Tesla's influence on the development of radio was known to but a limited number of people. A few eminent persons who attended or read his lectures during the 1890 decade were inspired by his revelations and some others, who later delved into the backgrounds of the art, became aware of the pioneering import of his contributions.

Far ahead of his time, mistaken as a dreamer by his contemporaries, Tesla stands out as not only a great inventor but, particularly in the field of radio, as the great teacher. His early uncanny insight into alternating current phenomena enabled him, perhaps more than any other, to create by his widespread lectures and demonstrations an intelligent understanding of them, and inspired others not yet acquainted with this almost unknown field of learning, exciting their interest in making improvements and practical applications. Many developments generally attributed to others had their genesis in the trail-blazing teachings of this pioneer genius.

A New Beam-Indexing Color Television Display System[*]

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Summary—**This paper describes a single-gun cathode-ray display system (the Apple System) for color television receivers based on the phenomenon of secondary emission. An index signal, derived from a secondary emissive structure built into the screen of the tube, continuously indicates the position of the scanning spot relative to the color phosphor structure. This positional information is combined with the color television signal, and the combined signal modulates the scanning spot in amplitude and phase in such a manner that the spot sequentially illuminates the primary colors in the appropriate amounts and proportions to reproduce the intended scene. This paper describes the general features of the system and the philosophy behind its development, and the derivation of the index signal and its utilization in the color-processing and grid-drive circuits.**

INTRODUCTION

FROM its inception many years ago, the aim of the Philco color television development program has been to produce a color television display in which the picture tube and its external beam-controlling parts are as simple as possible. Most other color display systems are based either on the premise that each of several color phosphors is excited by its own electron beam while being protected from the other beams by mechanical or electromechanical means, or, alternately, that a single electron beam is directed to several color phosphors by electromechanical means. These types of display require a mechanical structure within the tube and present problems in registration or focus, or both.

The beam-indexing system is based on the premise that a single electron beam can be used to excite the several color phosphors without auxiliary color deflection or beam shadowing. Instead of forcing the beam to land on a particular phosphor, the beam can be passed over all color phosphors in rapid succession and modulated in accordance with its position to produce the required color. Operation in accordance with this principle requires an indexing system to provide information concerning the whereabouts of the writing beam and a modulating system to provide the required beam modulation. The beam-indexing display system avoids the mechanical and registrational problems of other color

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